Hail detection algorithm for the GPM core satellite

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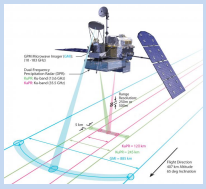
Curret hail detection algorithms based on spaceborne observations (Cecil et al. '08, '11, Ferraro et al. '13)

1. Mainly based on radiometric data, but also 40 dBZ Ku-reflectivity level height considered
2. Ground reports of hail used as “truth” (statistics partially biased by a small number of reports in rural areas)
3. Data from the United States used as a training basis for hail detection
4. Hail reports assigned to the storm if issued within a certain range and time from observations (temporal and spatial uncertainty)

Our methodology

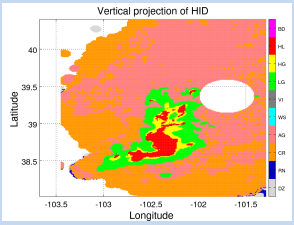
1.GPM core satellite's observations used for analysis



- Dual-frequency radar (Ka and Ku band)
- Radiometer system operating at 13 different channels ranging from 10 to 188 GHz
- Nonsun-synchronous orbit
- 65° inclination to obtain coverage of 90% of the globe

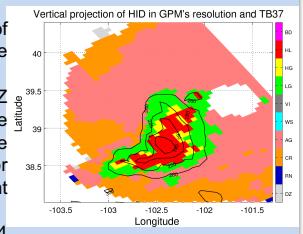
2.Data from the United States used as a training basis

3.No ground reports but the hydrometeor classification (HID) proposed by Dolan and Rutledge ('09) used as truth



- HID is based on measurements from S-band polarimetric radar data
- Four observables (reflectivity, differential reflectivity, cross-correlation coefficient, and “reflectivity texture”) and a temperature profile used for classification
- High hail detection capabilities

4. High resolution ground-based field of hydreometeor type averaged to the GPM footprint
5. The GPM observables like 40 dBZ level height, are mapped to the hydrometeor types retrieved from the NEXRAD measurements, e.g. for each BT pixel we assign a dominant hydrometeor type
6. Because HID is updated every 4 minutes we have nearly instantaneous matching



Results

RADAR-based proxies

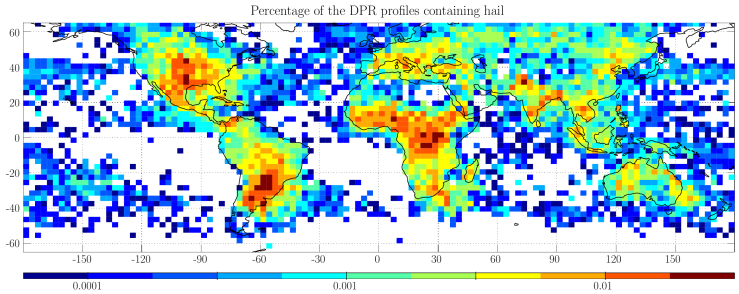
- The hail detection algorithm based on three of Ku-based parameters, $H40^{ku}$, Z_{int}^{ku}, Z_{mix}^{ku}, have nearly the same CSI of 40 % (FAR and POD oscillating around 45 % and 60 %, respectively)
- The simple measure of storm strength, Z_{max}^{ku}, performs very poorly.
- When 35 GHz radar measurements are considered, the best performing criteria for hail detection are based on $H30^{ka}$, Z_{int}^{ka}, Z_{mix}^{ka}

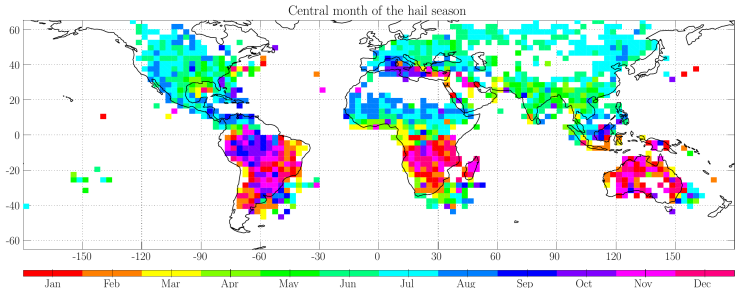
RADIOMETER-based proxies

- 37 and 89 GHz radiometric channels are the best hail indicators among all passive measurements available on board of the GPM satellite.
- Higher frequency TBs are not sensitive to high density ice.
- Low frequency channels are strongly dependent on emissivity of the underlying surface

Distribution of severe weather based on proxies on integrated reflectivity

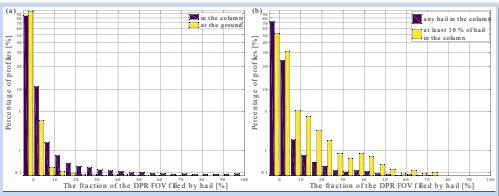
- Intense storms cluster in equatorial Africa, in the ”tornado alley” in the USA and in Argentina
- The region of severe weather in Northern America extends to the mid latitudes
- Other smaller regions affected by hail: the eastern shore of India, the southern slope of the Himalayas, South Africa, Indochina and the coast of the Yellow Sea.
- In Europe moderate hail-fall intensity, which decreases even more in northern Asia.
- Marine storms are less intense, typically located on the eastern shore of continents e.g. off the coast of Argentina, South Africa, Australia.



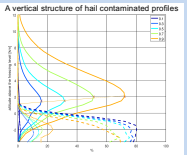


Statistical results at the ground

- Hail is very rare, even within intense storms
- Very strong non-uniform beam filling



(a) A histogram of all 71 thousand of DPR profiles used in our analysis. The yellow bars show how often a certain fraction of the DPR field of view is filled by hail in proximity to the surface, whereas the blue bars stratify the DPR profiles with respect to the biggest fraction occupied by hail in the column.
(b) The frequency of capturing a certain fraction of the DPR footprint filled by hail under condition that at least 0.1% or 10% of the DPR field of view was observed in the column.

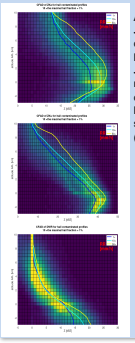


A vertical structure of hail contaminated profiles stratified according by the maximal fraction occupied by hail in the column (see legend).Continuous, dashed and dotted line represent the mean fraction occupied by hail, rain and big drops respectively.
The probability of hail-fall is inversely proportional to the freezing level height

A typical behaviour of DPR measurements for different hail conditions:

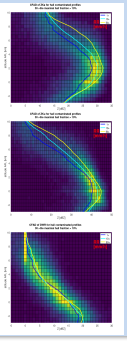
The contour lines show the median profile for different rain rates at the ground.

Minor hail contamination



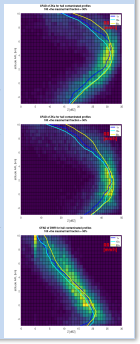
A single scattering situation:
. The peak of the reflectivities correspond to the freezing level(FL) height
. A drop in measured reflectivities below the FL is caused by attenuation by liquid water with sharper slopes for higher rain rates (RR)

Moderate hail contamination



Weak multiple scattering at Ka-band:
.The peak of the Ka-reflectivity is pushed above the FL
. Attenuation at Ka-band caused by rain partially compensated by multiple scattering
. No clear difference in the shape of DWR for different rain conditions

Severe hail contamination



Strong multiple scattering at Ka-band:
.Abnormal sloping of the median Ka-reflectivity profiles for all rain rates
.A phase change below the FL is not reflected in Ka-band measurements
.A characteristic “DWR knee”
.The Ku measurements may be also affected by multiple scattering→ no significant difference between slopes of the reflectivity below the FL for different rain rates.

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